

AD-A244 527



ESL-TR-88-49

1

**RECOVERY/RECHARGE AND RECYCLE
SYSTEM FOR BROMOCHLORODI-
FLUOROMETHANE (HALON 1211)**

**H. D. BEESON, B. R. DEES, J. D. WATSON, T. J.
STEPETIC**

**NEW MEXICO ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF NEW MEXICO
BOX 25
ALBUQUERQUE NM 87131**

NOVEMBER 1990

FINAL REPORT

SEPTEMBER 1986 - AUGUST 1987

**APPROVED FOR PUBLIC RELEASE: DISTRIBUTION
UNLIMITED**

**DTIC
ELECTE
JAN 17, 1992
S B D**

92-01512



**AIR FORCE ENGINEERING & SERVICES CENTER
ENGINEERING & SERVICES LABORATORY
TYNDALL AIR FORCE BASE, FLORIDA 32403**



NOTICE

The following commercial products (requiring Trademark®) are mentioned in this report. Because of the frequency of usage, the trademark was not indicated. If it becomes necessary to reproduce any segment of this document containing any of these names, this notice must be included as part of that reproduction.

See-All
Catch-All

Mention of the products listed above does not constitute Air Force endorsement or rejection of this product, and use of information contained herein for advertising purposes without obtaining clearance according to existing contractual agreements is prohibited.

PLEASE DO NOT REQUEST COPIES OF THIS REPORT FROM HQ AFESC/RD (ENGINEERING AND SERVICES LABORATORY). ADDITIONAL COPIES MAY BE PURCHASED FROM:

NATIONAL TECHNICAL INFORMATION SERVICE

5285 PORT ROYAL ROAD

SPRINGFIELD, VIRGINIA 22161

FEDERAL GOVERNMENT AGENCIES AND THEIR CONTRACTORS REGISTERED WITH DEFENSE TECHNICAL INFORMATION CENTER SHOULD DIRECT REQUESTS FOR COPIES OF THIS REPORT TO:

DEFENSE TECHNICAL INFORMATION CENTER

CAMERON STATION

ALEXANDRIA, VIRGINIA 22314

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release. Distribution unlimited.	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE			
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NMERI-32 (83204)		5. MONITORING ORGANIZATION REPORT NUMBER(S) ESL-TR-88-49	
6a. NAME OF PERFORMING ORGANIZATION New Mexico Engineering Research Institute	6b. OFFICE SYMBOL (If applicable) NMERI	7a. NAME OF MONITORING ORGANIZATION Engineering and Services Laboratory	
6c. ADDRESS (City, State and ZIP Code) Box 25, University of New Mexico Albuquerque, New Mexico 87131		7b. ADDRESS (City, State and ZIP Code) Air Force Engineering and Services Center Tyndall Air Force Base, Florida 32403	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Contract No. F08635-85-C-0129	
8c. ADDRESS (City, State and ZIP Code)		10. SOURCE OF FUNDING NOS.	
		PROGRAM ELEMENT NO.	PROJECT NO.
		TASK NO.	WORK UNIT NO.
11. TITLE (Include Security Classification) RECOVERY/RECHARGE AND RECYCLE SYSTEM FOR BROMOCHLORODIFLUOROMETHANE (HALON 1211)			
12. PERSONAL AUTHOR(S) Harold D. Beeson, Billy R. Dees, Jimmy D. Watson, and Thomas J. Stepetic			
13a. TYPE OF REPORT Final Report	13b. TIME COVERED FROM 9/27/86 TO 8/27/87	14. DATE OF REPORT (Yr., Mo., Day) 1990 November 3	15. PAGE COUNT 54
16. SUPPLEMENTARY NOTATION Availability of this report is specified on reverse of front cover.			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB GR	
		Recycle, Halon 1211, Transfer	
		Recharge, Moisture, Fire extinguisher,	
		Recover, Filter, Prototype	
19. ABSTRACT (Continue on reverse if necessary and identify by block number)			
<p>The Air Force has an extensive inventory of Halon 1211 fire extinguishers, all of which require service and maintenance. When these operations are performed, halon is vented to the atmosphere, resulting in an estimated loss of up to 250,000 pounds of halon per year at a value approaching \$500,000. Additionally, these emissions have a significant impact on stratospheric ozone. This project developed a recharge/recovery system for Halon 1211 to move the agent between vessels without venting, and to simultaneously determine the quality of the halon and remove contaminants. The project was accomplished in two phases. Phase I included a review of the commercial market and a summarization of available components. Phase II involved design, assembly, and testing. Over 200 transfer and recovery tests were performed on the prototype unit. The results of this effort are a prototype recharge/recovery unit for Halon 1211, operation and maintenance procedures, and a purchase description for use by the Air Force in procurement activities.</p>			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS <input type="checkbox"/>		21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Joseph Walker		22b. TELEPHONE NUMBER (Include Area Code) 904/283-3734	22c. OFFICE SYMBOL RDCF

DD FORM 1473, 83 APR

EDITION OF 1 JAN 73 IS OBSOLETE.

(The reverse of this page is blank.)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

RECOVERY/RECHARGE AND RECYCLE SYSTEM FOR
BROMOCHLORODIFLUOROMETHANE (HALON 1211)

EXECUTIVE SUMMARY

A. OBJECTIVE: This project was to develop a method, and construct a prototype system by which Halon 1211 could be effectively transferred between pressure vessels, and qualitatively diagnosed/purified during the transfer process.

B. BACKGROUND: The Air Force has an extensive inventory of Halon 1211 extinguishers, all of which require service and maintenance. When these operations are performed, halon is vented to the atmosphere, resulting in an estimated loss of up to 250,000 pounds per year at a value approaching \$500,000. Additionally, these emissions have a significantly adverse impact on stratospheric ozone. While some Air Force Fire Departments experimented with locally fabricated transfer systems, most of these systems did not significantly reduce the venting problem, and none of the systems ever incorporated any diagnostic/purification capability. The venting of Halon 1211 directly to the atmosphere is now coming under severe criticism with the increased publicity surrounding ozone depletion.

C. SCOPE: To develop and optimize a recharge/recovery system for Halon 1211, a review of the existing technology was conducted. Companies which market or are developing recharge apparatuses were contacted and literature was obtained. The apparatus which represented the closest approach to the project goals was purchased and tested. A request for proposal was submitted to each company contacted, and responses to the technical effort, which was similar in scope and design to the project outline, were sought. No formal responses were received; however, informal technical input was received from several sources and was essential to the completion of this portion of the task. The development of the prototype then consisted of the conceptualization, definition, and development of three subsystems: a contaminate removal system, a moisture measurement system, and a halon transfer system. Once the subsystems were defined, the necessary components were incorporated into a system design. The system was then constructed and presented with a project briefing at Warner Robins ALC, Robins AFB, Georgia.

D. METHODOLOGY: Distillation and filtration were considered for contaminate removal. Because distillation requires a complex, expensive, and fixed apparatus, filtration was selected. Testing of numerous filtration devices and media indicated that a single element, single pass system would fulfill the requirements. A commercially available unit employing activated alumina and molecular sieves was selected over the more expensive custom filter option. For moisture measurement, chemico-electric detectors, optical (IR) moisture meters, and metal salt color change moisture meters were investigated. Because of complexity, calibration

requirements, and expense, the first two options were eliminated, and the metal salt color change moisture meter, also known as a "dry eye" was selected for incorporation and testing. The available technologies for transfer of the halon were pumping and pressure. The use of pressure to transfer halon requires pressure regulation, and venting of any overpressure. Pressure transfer also requires additional plumbing. The advantages of using a pump to move the halon are that the system is able to recirculate the halon if necessary to assure quality, the operation of the system is simplified, and the losses associated with venting during pressure transfer are virtually eliminated.

E. TEST DESCRIPTION: All testing was performed at Tyndall AFB, FL. A total of 235 transfer evaluation tests were conducted in the following areas: (1) transfer and recovery tests with 150-pound flight line unit and nine-pound hand unit, (2) extinguisher hose compatibility and evacuation tests, and (3) transfer and recovery tests with the P-19 Crash Rescue vehicle. Filter tests were conducted with a starting water contents of 86 p/m and 310 p/m and a transfer rate of 12 lb/min. The filter reduced the water content to 10 and 13 p/m as confirmed by the Karl Fischer method. The moisture meter color change characteristics were in accordance with manufacturer specifications as confirmed by the Karl Fischer method.

F. RESULTS: The prototype system is well-designed but fails to have the pumping capability necessary to meet the desired requirements. The halon transfer rate in this type of pumping system is affected by the inlet supply to the system. Restrictions from the dip tube of a 1500-pound supply cylinder through the small 3/8-inch opening in the discharge valve on the tank cause a pressure drop, resulting in vaporization of halon which greatly reduces pump efficiency. Presently used extinguisher and storage cylinders are not configured for efficient and rapid transfer of halon between vessels. Some procedural and configuration changes are required. These changes are neither costly nor detrimental to firefighting operations. The filtration and indicator systems performed as expected and no changes are recommended to these systems.

G. CONCLUSIONS: A pump with increased capacity should be used. The pump should be of the type and size needed to transfer Halon 1211 between a truck-mounted or portable extinguisher unit and a storage cylinder at a rate on not less than 3 gal/min against an outlet gage pressure of 200 psi. The pump should also be able to develop a minimum vacuum of 12 inches of mercury under conditions of no inlet flow. To ensure a full supply of liquid halon to the pump, it is essential that the halon being transferred be removed from the bottom of the 1500-pound storage tank. To accomplish this it will be necessary to invert the storage cylinder on a locally manufactured stand and connect the input line of the transfer system to the vapor valve of the storage cylinder. As an option to eliminate the requirement of inverting the storage cylinder, a redesigned halon storage tank could be used. The storage tank should have a minimum capacity at a maximum fill ratio of 85 percent at 70 degrees F. and include properly sized inlet and outlet valves, pressure gage, pressure relief valves, and agent level gage. The tank

should be cylindrical, positioned with its axis horizontal or vertical, and mounted on a wheeled support system. When possible, a hose should be connected between the vapor dome of the supply and receiver tanks in order to equalize pressure between the tanks during servicing operations. When it is impractical to use a vapor line, it may be necessary to install a vacuum breaker connected to the vapor line of the supply cylinder. The installation of a vacuum breaker will ensure positive evacuation of the halon and prevent back siphoning during transfer operations. It is recommended that a vacuum breaker set to open at 1.5 inches of mercury be considered for this application. When long sections of extinguisher hose are evacuated in a closed system, it may be necessary to install a vacuum breaker on the extinguisher system. The breaker should be installed as a modification to the system and connected to the discharge side of the main halon discharge valve at or ahead of the hose connection. This will ensure positive evacuation of the hose and prevent back siphoning during evacuation. It is recommended that a vacuum breaker set to open at 1.5 inches of mercury be considered for this application.

H. **RECOMMENDATIONS:** A purchase description has been developed to describe a recycle/recovery which will effectively transfer Halon 1211 between pressure vessels while simultaneously removing moisture and other contaminants from the halon agent. Air Force implementation of this purchase description will produce a system which will effect a savings for all military services in agent replacement. Implementation of this system will also reduce halon emissions to the atmosphere during transfer and maintenance operations.



Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification _____	
By _____	
Distribution/ _____	
Availability Codes	
Dist	Avail and/or Special
A-1	

PREFACE

This report was prepared by the New Mexico Engineering Research Institute (NMERI), University of New Mexico, Campus Box 25, Albuquerque, New Mexico, 87131, under contract F08635-85-C-0129 (Subtask 83204 "Recycling Halon 1211"), for the Engineering and Services Laboratory, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida 32403.

CWO-4 Bobby F. Barrow was the project officer for HQ AFESC/RDCF. This report summarizes work done between 27 September 1986 and 27 August 1987.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

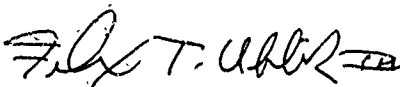
This technical report has been reviewed and is approved for publication.



JOSEPH L. WALKER
Chief, Airbase Fire Protection
and Crash Rescue Systems Branch



FRANK P. GALLAGHER III, Colonel, USAF
Director, Engineering and Services
Laboratory



FELIX T. UHLIR III, Lt Col, USAF
Chief, Engineering Research Division

TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION.....	1
	A. OBJECTIVE.....	1
	B. BACKGROUND.....	1
	C. SCOPE.....	3
II	TECHNOLOGY EVALUATION.....	4
	A. SYSTEMS EVALUATION.....	4
	B. COMMERCIAL SYSTEM TEST AND EVALUATION.....	5
III	PROTOTYPE DEVELOPMENT.....	7
	A. CONTAMINANT REMOVAL SYSTEM.....	7
	B. MOISTURE MEASUREMENT SYSTEM.....	12
	C. HALON TRANSFER SYSTEM.....	14
	D. SYSTEM DESIGN AND CONSTRUCTION.....	15
	E. BRIEFING AND SYSTEM DEMONSTRATION.....	16
IV	SYSTEM TEST AND EVALUATION.....	19
	A. ONE-HUNDRED-FIFTY-POUND WHEELED UNIT--TRANSFER (T) AND RECOVERY (R).....	19
	B. NINE-POUND HAND UNIT--TRANSFER (T) AND RECOVERY (R).....	23
	C. P-19--TRANSFER (T) AND RECOVERY (R).....	24
	D. HOSE COMPATIBILITY AND TRANSFER TESTS.....	25
	E. RECIRCULATION TESTS.....	26
	F. TEST DATA AND NOTES.....	27
V	CONCLUSIONS AND RECOMMENDATIONS.....	28
	A. CONCLUSIONS.....	28
	B. RECOMMENDATIONS.....	28
	REFERENCES.....	30
	BIBLIOGRAPHY.....	31
APPENDIX		
A	DRAFT PURCHASE DESCRIPTION, RECHARGE/RECOVERY UNIT FOR BROMOCHLORODIFLUOROMETHANE.....	33
B	PRODUCTION AND LIFE CYCLE COST ANALYSIS.....	51

SECTION I INTRODUCTION

A. OBJECTIVE

The objective of this effort was to identify, assemble, test, and validate a device which can effectively transfer Halon 1211 between pressure vessels while simultaneously removing moisture and other contaminants from the halon agent. A coordinated transfer system was assembled with complete operating procedures and a draft purchase description was developed.

B. BACKGROUND

Estimates show that 121,850 portable fire extinguishers (including 150-pound wheeled units) and 620 skid- and vehicle-mounted units (averaging 500 pounds) are now in the Air Force inventory (Reference 1). These units collectively contain approximately 3.5 million pounds of Halon 1211. All extinguishing units in the inventory are subject to service and maintenance operations. Approximately 1 million pounds of Halon 1211 were involved in reservicing operations during 1986 (Reference 1). Because of current reservicing procedures, large amounts of halon are discharged into the atmosphere. This loss is particularly acute during the servicing of portable Halon 1211 units, which must be emptied for servicing. All pressure vessels must now be hydrostatically tested on a given cycle, depending upon use. Additionally, routine maintenance operations may require that the halon contained within an extinguisher be removed. The amount of halon discharged into the atmosphere during servicing operations has been conservatively estimated at 80,000 pounds per year (Reference 1) and may be as high as 250,000 pounds per year. The dollar loss associated with the discharge of agent to the atmosphere is significant, approaching \$500,000 per year.

With existing techniques, Halon 1211 can be recovered from extinguisher units and placed in a storage cylinder, where it may be recycled back into an extinguisher unit. The recovered halon is of questionable quality, and may be contaminated with water, acids, oils, or particulates.

Contaminants of Halon 1211 arise from either moisture contamination (water, acid, or particulates from rust and scale) or oily materials from transfer hoses and oil used for corrosion protection of metal parts. No method is now available to remove contaminants from the halon and assure the quality of recovered/recycled agent. The inability to assure the agent quality and the additional maintenance time required to recover the halon encourage agent discharge rather than recovery.

Contamination of halon with moisture is a major problem; moisture causes halon decomposition and formation of acids, which can corrode equipment. Halon, as purchased, has a maximum specified moisture content of 20 p/m, and usually contains 6-10 p/m of water. Moisture is introduced into the halon in several ways: servicing operations, use under humid conditions, not removing moist air from extinguishers that have been allowed to remain open in contact with the atmosphere (through evacuation or nitrogen purge prior to recharge), not drying extinguishers completely after hydrostatic testing, and charging extinguishers or truck-mounted units with moist compressed air. The contamination of Halon 1211 by pressurizing the system with compressed air which has not been dried is particularly acute on the larger truck mounted system, where typically the full halon charge is not expelled before the system is depressurized, recharged, and placed back into service. Repeated repressurization with moist compressed air severely compromises system integrity. Compressed air should not be used to charge extinguishers unless it has been dried by an AD-800 filter unit; however, these filter units are also used when charging breathing air bottles, and possible contamination of the breathing air with halon limits the filter's use with extinguisher systems.

Both a dollar loss and an environmental impact are associated with the discharge of halon of uncertain quality into the atmosphere. The release of halogenated hydrocarbons, including halons, is believed to deplete stratospheric ozone. The Environmental Protection Agency (EPA) is considering restricting halon emissions. These restrictions could include reporting emissions during servicing operations. Thus, any recharge/ recovery unit developed as part of the present effort must limit halon emissions during servicing operations.

C. SCOPE

The present effort to develop a recharge/recovery system for Halon 1211 was accomplished in two phases: Phase I--Design, and Phase II--Construction and Testing. The design phase included a thorough review of the commercial market for applicable components which might be used in an apparatus for transferring Halon 1211 between pressure vessels. Following the technology evaluation, a halon recharge/recovery system was designed, assembled, and tested. The system testing consisted of analyzing the transferred halon for quality, and evaluating the recharge/recovery system for transfer effectiveness, operability, and maintainability. The results of this effort are a coordinated recharge/recovery system for Halon 1211, complete with operation and maintenance procedures, and a purchase description for use by the Air Force in procurement activities.

SECTION II

TECHNOLOGY EVALUATION

To develop and optimize a recharge/recovery system for Halon 1211, a review of the existing technology was conducted. Companies which market or are developing recharge apparatuses for Halon 1211 were contacted and literature was obtained. The apparatus which represented the closest approach to the goals of the present effort was then purchased and tested. A request for proposal was also submitted to each company contacted, and responses to the technical effort, which was similar in scope and design to the subtask statement of work, were sought. Because of conflict-of-interest restrictions, this approach received little response; however, informal technical input received from manufacturers was essential to the completion of this task and is included in this report as appropriate.

A. SYSTEMS EVALUATION

Five companies were contacted regarding their Halon 1211 recharge apparatus. The five companies were Amerex Corporation, Ansul Fire Protection, Badger-Powhatan, Protectoseal Company which currently markets Halon 1211 recharge apparatus, and Feecon Corporation which was in the process of developing an apparatus for commercial use. All currently available systems are pressure transfer systems, which use nitrogen pressurization to push the halon from a bulk storage container into the extinguisher.

In general, a pressure transfer of Halon 1211 operates as follows. Prior to recharge, the extinguisher to be serviced is dried by hot air (if liquid water is present) followed by either evacuation or purging of the extinguisher with nitrogen to remove any moist air. The depressurized extinguisher is then placed on a scale, and a tare weight is recorded. The extinguisher is filled with the proper amount of Halon 1211 by pressurizing the vapor dome of the supply cylinder and allowing the nitrogen pressurization to push the halon into the extinguisher unit, usually through the discharge valve. More detailed instructions for recharge may be found in the associated Technical Order for the equipment of interest.

Based on a review of the literature provided by the manufacturers, a decision was made to evaluate the recharge/recovery system manufactured by Amerex Corporation. This choice was based on the following observations. Of the commercially available units, the Ansul, Protectoseal, and Badger-Powhatan units were all essentially the same. All three units use 1/4-inch transfer hoses, which make transfer of agent into the larger units very slow. The instructions for use of the three units were for hand-held portables only and covered no recovery procedures. The Amerex system consisted of four items: a recharge/recovery unit for hand-held extinguishers, a recharge/recovery unit for wheeled and truck-mounted extinguishers, a vacuum pump for removing moist air prior to recharge, and a slide/tape presentation for military extinguisher service and maintenance. The system contained both 1/4-inch and 1/2-inch hoses with a full set of adapters to charge hand-held, 150-pound wheeled, and 500-pound truck-mounted extinguishers. The larger hoses allow more rapid filling of the 500-pound and 150-pound units. The Amerex system contained complete instructions for recharge and recovery of halon from any extinguisher system, including all common military halon extinguishers. The slide/tape presentation was directed toward servicing of hand-portable units and emphasized a comprehensive servicing program.

From the scope and objective of the present task, it was determined that the Amerex system approached most closely the goals of the present effort. Four units were purchased from Amerex and were tested to evaluate the possibility of system modification for effective recycling of Halon 1211.

B. COMMERCIAL SYSTEM TEST AND EVALUATION

Tests were conducted with the commercial recharge/recovery units. The tests consisted of five transfers of approximately 150 pounds of halon from a flight line wheeled unit. Transfers were conducted following the instructions provided by the manufacturer. Flow rate and transfer time data were collected. Initially a flow rate of 12-15 lb/min was attained; however, as pressure equalized, the transfer rate slowed to approximately 2 lb/min. Once the pressure equalized, the storage cylinder required venting to complete the transfer. The average time for the five transfers was 18.4 minutes for an average rate of 8.15 lb/min.

Tests were also conducted to evaluate the efficiency of the vacuum pump in removing moist air from an extinguisher. The vacuum pump was connected to the 150-pound wheeled unit following the manufacturer's instructions, and the resulting vacuum was recorded. Initially the pump was able to pull only 8 inches of mercury vacuum due to leaks in the quick-connect joints. After the quick-connects were adjusted to seal more effectively, a vacuum of 14 inches of mercury was observed. This reduction in pressure to 0.5 atmospheres reduces the water content by a factor of only 0.5. Pressurizing the extinguisher to 100 lb/in² with dry nitrogen and releasing the pressure give a 70-percent reduction in water content (as calculated using fundamental gas laws), and results in a more efficient displacement of moisture from the system.

These tests showed that improvements could be made in the system by using a pump to reduce the amount of venting required. Furthermore, since the evaluated system was essentially hoses and fittings, any system developed as a result of this effort would need to incorporate the basic elements of the evaluated recharge/recovery system.

SECTION III

PROTOTYPE DEVELOPMENT

The development of a prototype recharge/recovery system for recycling Halon 1211 consisted of the conceptualization, definition, and development of three subsystems: a contaminate removal system, a moisture measurement system, and a halon transfer system. Once the subsystems were defined, the necessary components were incorporated into a system design (Figure 1). The system was then constructed and presented with a project briefing at Warner Robins ALC, Robins AFB, Georgia.

A. CONTAMINANT REMOVAL SYSTEM

1. Concept Development

Two concepts were considered for contaminant removal: distillation and filtration*. Discussions were held with personnel from Great Lakes Chemical Company and ICI Americas Incorporated on factory processes for the recovery of Halon 1211 that did not meet specified contaminant limits. Both companies either vent out-of-specification halon to the atmosphere or redistill the material at the plant. Distillation does not represent a viable solution to contaminant removal, since the apparatus required is complex, expensive, and nonportable. Filtration is a more practical method of contaminant removal in a field recharge/recovery system.

Several original equipment manufacturers (OEM) have installed filtration systems on their large halon storage tanks for continuous circulation and drying of halon. Amerex has a molecular sieve bed which treats approximately 1 million pounds of halon each year. The Amerex drying system maintains the halon in a bulk storage tank with less than 6 p/m moisture.

Although the technical requirements for this project specified only the removal of moisture, the removal of other contaminants, such as

* Throughout this report, the terms "filtration" and "filter" refer to any process involving passage of halon through a unit for filtration of particulates and sorption of contaminants.

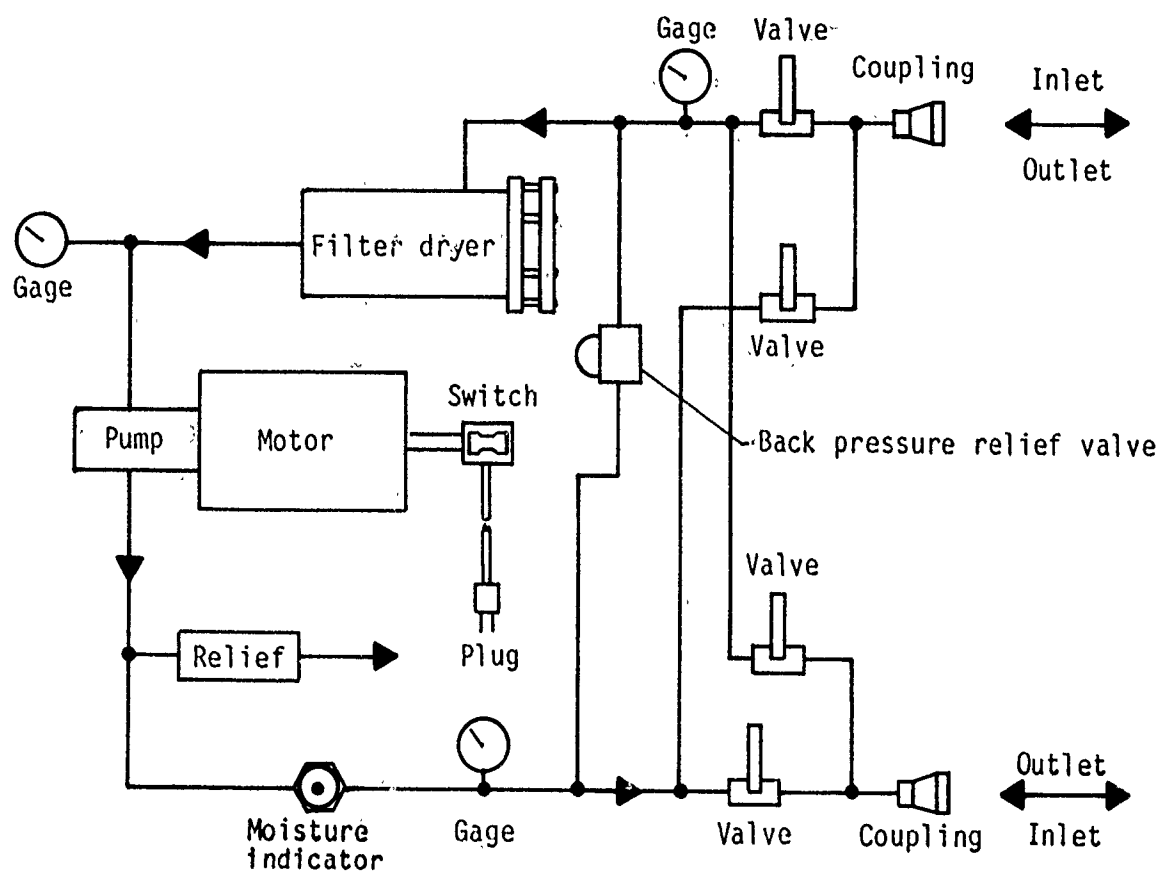


Figure 1. Halon 1211 Recovery/Charging System.

acids, particulates, and oils, is important. The goals of the contaminant removal process were to meet the moisture content specification for the recycled halon and to simultaneously remove as many other contaminants as practicable.

The use and effectiveness of various filtration and sorption media were tested to determine contaminant removal efficiencies. Halon 2402 was used in the initial testing and concept development because it could be easily handled without the use of specialized equipment. Analysis of Halon 2402 following procedures described previously (Reference 2) gave a total acid content of 250 ppmv and an indeterminable amount of water. The contaminated halon was passed through anhydrous calcium carbonate to reduce the total acids to 80 ppmv. The treated Halon 2402 was again passed through calcium carbonate and through decolorizing carbon to give a total water of less than 50 ppmv. The Halon 2402 was then dried over molecular sieves for 8 hours to give total acid and water contents of less than 1 ppmv and 22 ppmv, respectively. This experiment showed that halon which greatly exceeds specified contaminant levels can be made to conform to specification by filtration and sorption.

Based on the results of this experiment, a three-stage filter was developed for testing. The first stage contained decolorizing carbon to remove particulate matter and oils. The second element contained anhydrous calcium carbonate to reduce the acid content of the halon and to partially remove moisture. Anhydrous calcium carbonate was used in these experiments; however, materials such as anhydrous sodium sulfate or activated alumina should also be effective. The third element was a series of molecular sieves to remove remaining water from the halon.

The three elements were placed in a glass column. The decolorizing carbon was divided in half, and the column was packed so that decolorizing carbon was followed in turn by anhydrous calcium carbonate, molecular sieves, and the remaining decolorizing carbon. An aliquot of the contaminated Halon 2402 used earlier was passed through the column and collected. The treated halon was analyzed and found to contain 20 ppmv total moisture and less than 1 ppmv total acid. Following analysis, the halon was allowed to evaporate to determine if any oil was present; no oil or sediment were

observed. Investigations were then conducted into the availability of filter units to remove contaminants from recovered halon.

2. Definition of Components

The testing accomplished during concept development showed that halon could be decontaminated by a single pass through an appropriate unit. A search was conducted for a filter system to incorporate into the recharge/recovery system developed in the present effort. The requirements were that the filter system be simple, maintainable, and portable. Two possible systems were found. One option was to incorporate a commercially available filter, such as those used in the refrigeration industry. Local refrigeration supply houses were contacted and information was gathered regarding available filter-driers for refrigerants. Such systems are designed for inline removal of contaminants in refrigerant systems and cost approximately \$125. Based on available information, the Catch-All replaceable-core-type filter, manufactured by Sporlan Valve Company, was investigated. Testing for one-pass filtration sorption and ability to operate at flow rates of 12 lb/min was conducted and is discussed below.

The second option was to incorporate a custom filter into the system. This option was investigated by contacting the Adsorbents & Desiccants Corporation of America (ADCOA) and asking their personnel to calculate the requirements for a filter to meet the project needs. ADCOA predicted that to accomplish the task three packed columns would be required. The columns would be 2-inches in diameter and 4 feet long with a capacity of 40 tons of halon before saturation and would cost \$200 each. It was decided to pursue the more compact, more maintainable, and less expensive option of using commercially available filters.

The Sporlan filter unit (Reference 3) consists of a filter housing and a replaceable core filter. The housing is a steel shell with a safe working pressure of 500 lb/in². The shells are available in a range of sizes capable of incorporating between one and four filter cores per shell depending on the requirements of the application. The molded porous core elements are composed of several desiccants which include activated alumina and molecular sieves. The elements are capable of removing moisture, acids,

particulate matter, and oils from refrigerants. The cores are attached to an end-plate using tie rods and placed inside the filter shell. The end-plate is secured to the shell using eight bolts. Gaskets are used at the outlet seal to prevent bypassing of the refrigerant around the filter core. The high-water-capacity filter elements contain 48 in³ of desiccant and have a water capacity of 30 ml. A calculation of the amount of Halon 1211 which can be passed through the Sporlan unit before saturation--if the moisture content of the halon is reduced from 80 p/m (the saturation limit of Halon 1211) to 30 p/m--shows that 2000 pounds of Halon could be treated before the core would need to be replaced.

3. Testing

A Catch-All type C-485-G filter housing and a RCW-48 high-water-capacity filter core, manufactured by Sporlan Valve Company, were purchased from a local refrigeration supply house and evaluated. Tests were conducted to assess the ability of the filter to remove moisture from the Halon 1211 in a single pass. Two tests were conducted. In the first test 5 pounds of Halon 1211 were analyzed for moisture content by the Karl Fischer method and found to contain 10 p/m moisture. Sufficient water was added to give a total moisture content of 86 p/m. The halon was then transferred through the filter unit at a rate of 12 lb/min and collected in a clean and dry pressure vessel. The transferred halon was analyzed for moisture and was found to contain less than 10 p/m water as determined by Karl Fischer analysis.

In the second test, 5 pounds of Halon 1211 with an analyzed moisture content of 10 p/m were seeded with sufficient water to bring the total moisture content to 310 p/m. The contaminated halon was then passed through the filter unit at a rate of 12 lb/min and collected in a clean and dry pressure vessel. The filtered halon was then analyzed for moisture content, which was determined to be less than 13 p/m.

These results show that the filter unit tested is capable of reducing the moisture content of Halon 1211 from the saturation point of 80 p/m, or from an excess water condition of 300 p/m, to within specified limits on a single pass through the filter. In the final design, described

later in this section, recovered halon is filtered at least twice--once upon recovery and a second time when the recovered agent is used for recharging extinguishers. If necessary, the recharge/recovery system can be connected to a storage cylinder in such a way that the halon is recirculated through the filter for multiple passes, thus ensuring that the maximum possible amount of moisture is removed.

B. MOISTURE MEASUREMENT SYSTEM

1. Concept Development

The developed system is required to have a quality assurance system to meter the moisture content of the recycled halon. The moisture meter was required to function in-line within the expected range of 5 to 80 p/m moisture content, to be easily operated by personnel using the system, and to be reliable and maintainable. Several manufacturers of trace moisture analyzers were contacted to obtain information on available technologies for moisture determination. The available technologies include electronic meters incorporating either chemico-electric detection or optical (IR) detection of moisture, and moisture indicators that function by color changes in a metal salt.

Electronic trace moisture indicators are sensitive, accurate, and precise; however, they are inappropriate for the present task for several reasons. Electronic meters require extensive maintenance and continual calibration. These meters are also complex to operate making them incompatible with requirements for field use. The electronic meters which were investigated determine moisture content only in the gaseous phase. Their incorporation into the present system would require extensive plumbing to obtain a liquid sample, vaporize it, meter the moisture content, and reliquify the sample. Finally, in-line electronic meters cost between \$2500 and \$10,000, depending on the technology used.

Moisture content indicators that give a color change for a metal salt are known as "dry-eye" indicators. They are simple to operate, easily maintainable, accurate, and reliable. Dry-eye indicators, however, are not precise. They usually indicate a moisture range. Moreover, the moisture

indication requires time for the reaction between water in the halon and the metal salt to reach equilibrium. Considering the objective of the present effort, and the fact that these indicators give an accurate indication of moisture content and cost approximately \$25, it was decided that these indicators could be incorporated into a properly designed recharge/recovery system and ensure the quality of the recycled halon.

2. Definition of Components

There are several manufacturers of dry-eye indicators for refrigerant gases. Most indicators have similar features and operating ranges. For this project the indicator selected for evaluation was the See-All moisture liquid indicator manufactured by Sporlan Valve Company, the manufacturer of the filter unit selected. The Sporlan indicator offers several desirable features. It indicates both moisture content and the presence of liquid halon in the same element. The presence of liquid is shown by a large sight-glass which surrounds the moisture indicator. Moisture is indicated by the color change that occurs when water present in the halon contacts the metal salt, which is impregnated in a filter paper element. If damaged during use, the paper element is replaceable without removing the indicator from the line by access through a plug in the back of the indicator. Replacement indicators cost approximately \$0.21. The color change is reversible depending on the moisture content of the halon.

According to the manufacturer, the response of the moisture indicator to Halon 1211 is similar to the response to R-113. The meter indicates that the moisture content of Halon 1211 is below 20 p/m by a dark green color for the indicator paper. The paper changes to chartreuse in the range of 20-65 p/m to indicate a caution region, and to a bright yellow color above 65 p/m to indicate that the halon is wet. The color changes are temperature-dependent; the above ranges are applicable at room temperature. The temperature dependence of the color change is not expected to be as great for Halon 1211 as for other refrigerants because the moisture saturation level of Halon 1211 is less temperature-dependent than other refrigerants (Reference 4). It is anticipated that the color change regions indicated above are applicable over the range of temperatures anticipated for the developed system.

3. Testing

A See-All moisture indicator was purchased from a local refrigeration supply company and installed in-line following the filter. During the transfer any change in the moisture indicator was noted. During the first test, described above, the indicator which was initially yellow due to contact with the room air turned to chartreuse during the transfer which lasted approximately 20 seconds. The indicator was observed further after the transfer, and it was noted that within 15 minutes the indicator had turned green from contact with the remaining vapors in the transfer line. In the second test the filter remained green during and after the transfer operation. These tests indicate that the moisture indicator is appropriate for use in the proposed system.

C. HALON TRANSFER SYSTEM

1. Concept Development

The pressure transfer system is comprised of all of the hoses, fittings, and plumbing associated with the movement of the halon from the pressure vessel, through the filter and meter, and into another vessel. There are two methods for moving the agent through the system: pressure, and pumping. The use of pressure to transfer halon required pressure regulation and venting of any overpressurization. Pressure transfer also requires additional plumbing. A pump can simplify the transfer process. Thus, the advantages of using a pump to move the halon are that the system is able to recirculate the halon if necessary to assure quality, the operation of the system is simplified, and the losses associated with venting during pressure transfer are essentially eliminated.

To be used on the transfer system a pump must be (1) capable of operation at flow rates up to 3 gal/min, (2) compatible with Halon 1211, which is a nonlubricating fluid, (3) able to transfer both liquid halon and any vapors down to atmospheric pressure in the transfer container, and (4) able to operate with an inlet pressure of atmospheric to 200 lb/in² against a head pressure of 22 to 200 lb/in². To fulfill these requirements positive displacement pumps, such as spur-gear, diaphragm, and piston were investigated.

D. SYSTEM DESIGN AND CONSTRUCTION

Upon identification of the major components of the system, the requirements of the prototype were defined and a design for the system was conceptualized. The major components of the prototype system were identified as: (1) a pump to transfer the halon and residual vapor between pressure vessels, (2) a filter unit to extract moisture, particulates, oils, and acids, and (3) a meter to ensure the quality of the transferred halon. The prototype system was required to operate in three modes--perform recharge/recovery operations on any portable or truck-mounted extinguisher in the Air Force inventory, be safe to operate, and be reliable and maintainable. The performance requirements were that the unit be able to transfer Halon 1211 between pressure vessels at a rate of 12 lb/min (the rate of pressure transfer), and effectively fill a small hand-portable extinguisher. The three modes of operation were defined as the recharge mode, where halon is transferred from a storage cylinder to an extinguisher unit; the recovery mode, where halon is transferred from an extinguisher unit to a storage vessel; and the recirculation mode, where halon is recirculated in either a storage vessel or truck-mounted unit to clean the agent.

At this point in the design and development, Feecon Corporation, which was in the process of developing a recharge/recovery apparatus for Halon 1211, offered a system on a nonobligatory basis for evaluation. Feecon's design incorporated several of the elements developed in this effort. The unit incorporated a Sporlan Catch-All filter unit with two cores, a Sec-All meter, and a magnetically-driven spur-gear pump. As a safety factor, the pump had a bypass that opened to full flow at a pressure of 40 lb/in², in the event that the pump dead-heads. The unit interfaced to the various storage cylinders and extinguisher units by means of double-seal quick-connects, which acted as shutoff valves to reduce halon loss when transfer hoses were uncoupled. The transfer hoses were made of a halon-resistant material and rated to 500 lb/in², while the tubing that connected the various subsystems was aircraft quality nylon hydraulic tubing rated to 2000 lb/in². The flow of halon through the system was from the filter through the meter and then through the pump.

The unit, shown in Figure 2, met the requirements that the unit be portable and compact. The packaged unit weighed 50 pounds and was placed on wheels for easy movement. The transfer hoses wrapped around a short handle for easy accessibility. The unit was delivered for presentation to the Air Force at a briefing and demonstration held at Warner Robins ALC on 28 April 1987.

E. BRIEFING AND SYSTEM DEMONSTRATION

A briefing on this effort was presented at Warner Robins AFB, Georgia, on 28 April 1987. In attendance at the briefing were the HQ AFESC/RDCF project officer; representatives from Warner Robins ALC/MMVRDV; representatives from HQ AFESC/DEF; and representatives from the Army, Navy, Marines, and private industry. During the briefing the constructed prototype, which had been offered on a nonobligatory basis by Feecon Corporation, was demonstrated. The ability of the prototype to perform recharge/recovery operations on a 150-pound wheeled unit, a 9-pound hand-held extinguisher, and a P-19 crash fire vehicle was demonstrated as was the unit's ability to recirculate the agent in a storage cylinder and to remove Halon 1211 from a charged handline. During the demonstrations over 1000 pounds of Halon 1211 were transferred between various pressure vessels with an estimated loss of less than 10 pounds. After the demonstration a critique of the unit was conducted.

The discussions, demonstration, and critique brought out many means of improving the prototype system. The advantages of the prototype system are the ability of the system to recirculate the Halon 1211 in a vessel, to clean the agent without having to transfer, to transfer without nitrogen overpressurization and associated venting, to continuously clean and dry the transferred agent, and to remove the agent from a charged handline without using the truck nitrogen system, thus reducing a large source of agent loss. The drawbacks of the prototype system were seen as the low flow rate for larger systems (HQ AFESC/DEF would like to charge a 500-pound halon system on a P-19 in 10 minutes), the inefficiency of the system in transferring vapor, and the top end pressure of the system (40 lb/in² before the pump bypass opens).

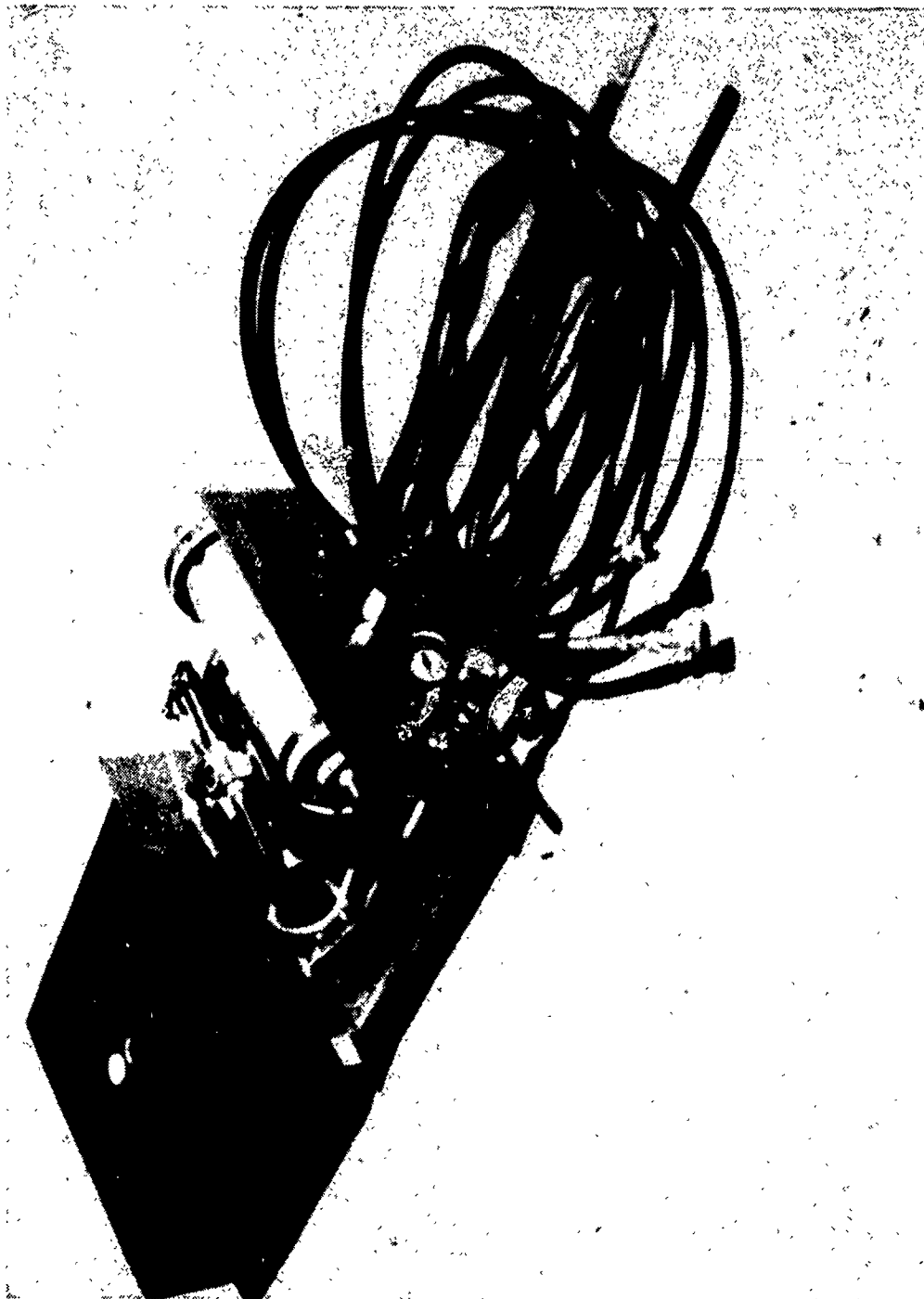


Figure 2. Prototype Halon 1211 Recharge/Recovery Unit.

On 29 April a series of transfers was accomplished between a 150-pound wheeled unit and a 200-pound storage cylinder to assess possible modifications to the system to reduce the drawbacks described above. These tests indicated that the system could be improved by the following: (1) increasing the top end pressure to 150 lb/in² by replacing the valve on the pump bypass, (2) increasing the size of the tubing and hoses in the system to reduce the pressure drop through the system and to increase the flow rate and transfer efficiency, and (3) evaluating the pump efficiency at differential pressures of 100 lb/in² to determine if a different pump were required. Feecon Corporation volunteered to modify the prototype system to improve the performance. Feecon determined that initial claims by the pump distributor were erroneous and that the pump was not capable of pumping at differential pressures greater than 50 lb/in². A different pump was, therefore, installed in the system. The new pump was placed before the filter and meter in anticipation that the elimination of the pressure drop through the filter and meter would increase the pump efficiency. The modified system was then subjected to test and evaluation.

SECTION IV SYSTEM TEST AND EVALUATION

The recharge/recovery system developed as a result of this effort was subjected to testing to evaluate effectiveness, reliability, and maintainability. In general, the system was tested against the Draft Purchase Description (Appendix A) developed for the system based on the prototype design and system requirements. A descriptive listing of the most significant tests and results follows; the overall procedures followed are those described in the Draft Purchase Description. All pressures given are pressures in excess of atmospheric (gauge pressures).

A. ONE-HUNDRED-FIFTY-POUND WHEELED UNIT--TRANSFER (T) AND RECOVERY (R)

TEST AT-1. The inlet line of the system was connected to the liquid line of a 150-pound wheeled unit. The discharge line from the system was connected to a vented storage tank. The system transferred 118 pounds of halon in 5 minutes. The halon transfer rate observed during this test was approximately 23 lb/min.

TEST AT-2. The inlet line of the system was connected to the liquid line of a 150-pound wheeled unit. The outlet line of the system was connected to the inlet line of a 200-pound storage tank. The storage tank was empty and at atmospheric pressure. The wheeled unit weighed 238 pounds and was charged with nitrogen to 155 lb/in². The system was turned on. After 2 minutes and 45 seconds, the weight of the wheeled unit was 86 pounds and the inside pressure was 50 lb/in². At this point, 8 pounds of halon remained in the wheeled unit.

TEST AT-3. The system was set up to pump from a full 150-pound wheeled unit, pressurized with nitrogen to 200 lb/in², into the top of a 45-gallon storage tank. The system was turned on and after 2 minutes of pumping the system stopped pumping liquid, indicating that the dip tube in the unit was no longer in contact with liquid. The weight of the wheeled unit at this point was 84 pounds. Six pounds of halon remained in the unit. The system was restarted and operated for 1 minute, reducing the weight of the unit by 0.5 pound. At the end of this test, the pressure in the wheeled unit was 25 lb/in², and the pressure of the recovery tank was 48 lb/in².

TEST AT-4. The system was connected to the pump from a 150-pound wheeled unit into a 45-gallon recovery tank. The weight of the wheeled unit was 227 pounds at 45 lb/in². The pressure of the recovery tank was 45 lb/in². After 6 minutes and 45 seconds of pumping time, the weight of the wheeled unit was 95 pounds. The system had stopped pumping liquid at this point, indicating that the dip tube of the wheeled unit was no longer in contact with liquid; 17.5 pounds of halon remained in the unit.

TEST AT-5. The system was connected to pump from a 150-pound wheeled unit to a storage tank. After 7 minutes of pumping, the wheeled unit's weight had been reduced to 86 pounds. At this point the wheeled unit was charged with nitrogen to 125 lb/in². The system was turned on again and run for 1 minute to reduce the weight to 84.5 pounds. At this point, 14.5 pounds of halon remained in the unit. By tipping the wheeled unit back onto its wheels by 20 to 30 degrees, the system reduced the weight to 78 pounds. This left only 8 pounds of halon remaining in the unit.

TEST AT-6. The system was connected from a 150-pound wheeled unit to pump into a storage tank. The wheeled unit weight was 235 pounds at 20 lb/in². The storage tank was at 20 lb/in². The system was turned on and after 9 minutes and 30 seconds of pumping, the wheeled unit weight was reduced to 78 pounds. At this point the wheeled unit was tipped 20 to 30 degrees to put the dip tube in contact with the remaining liquid halon. The pump continued to run for 1 minute. The system was then disconnected from the unit. The wheeled unit weight was reduced to 74 pounds; 4 pounds of halon remained in the unit. Venting to the atmosphere reduced the weight to 70.125 pounds, indicating that 0.125 pound of liquid halon remained in the unit.

TEST AT-7. The system was connected between a fully charged 150-pound wheeled unit and a storage tank. The pressure of the wheeled unit was 200 lb/in². The pressure of the storage tank was approximately 10 lb/in². The system was turned on and after 2 minutes and 5 seconds of pumping the weight of the wheeled unit was 78 pounds at 75 lb/in². The unit was tipped

back onto its wheels 20 to 30 degrees, and the system was run for 1 minute. The wheeled unit weight at this point was 76.5 pounds with 6.5 pounds of halon remaining in the unit.

TEST AT-8. The system was connected to pump from a full unit having a weight of 220 pounds at 40 lb/in² to an empty unit with a weight of 70 pounds at 0 lb/in². The halon transferred as a function of time is presented below.

Halon transfer	
Pumping time	Halon transferred, lb
46 s	25
2 min 16 s	50
5 min 19 s	75
9 min 20 s	100

At this point the system stopped pumping liquid. The inlet pressure of the system was approximately 10 lb/in². The flow stoppage could have been caused by heat from the motor being transferred through the pump shaft into the pump, causing the halon to vaporize inside the pump. The unit being emptied was charged to 25 lb/in² with nitrogen. The system was turned on again. The final weight of the unit was 78 pounds with 8 pounds of halon remaining.

TEST AR-1. The system was connected to pump from a 45-gallon storage tank into a 150-pound wheeled unit. The weight of the wheeled unit was 77.5 pounds at 0 lb/in². The pressure of the storage tank was 70 lb/in². After 4 minutes and 15 seconds of pumping time, the wheeled unit was filled to give a weight of 227.5 pounds at 25 lb/in².

TEST AR-2. The system was connected to pump from the storage tank into a wheeled unit having a weight of 78 pounds at 0 lb/in². A liquid flow meter was connected in-line from the system to the unit. The system was turned on. The flow rate varied between 1 and 5 gal/min on the meter with the system setting on a work bench 30.5 inches above the floor. The weight of halon transferred as a function of time is presented on the following page.

Halon transfer

Pumping time	Halon Transferred, lb
2 min 25 s	25
5 min 12 s	50
8 min 16 s	75
14 min 16 s	100

After 27 minutes and 13 seconds of pumping time, the weight of the wheeled unit was 192 pounds. At this point the system stopped pumping liquid. The storage tank had halon remaining in it at a pressure of 10 lb/in². The system seemed to lose prime even with positive pressure remaining in the storage tank. The loss of prime at this point could have been caused by heat transfer from the motor through the pump shaft, causing the halon to vaporize in the pump.

TEST AR-3. The system, which was placed on the floor, was connected to pump from a storage tank into a 150-pound wheeled unit. The weight of the wheeled unit was 78 pounds at 0 lb/in². The storage tank pressure was approximately 10 lb/in². The weight of halon transferred as a function of time is given below.

Halon transfer

Pumping time	Halon transferred, lb
1 min 7 s	25
2 min 14 s	50
3 min 45 s	75
5 min 45 s	100
8 min 5 s	125
11 min 7 s	150

TEST AR-4. The system was connected to pump from a storage tank into a 150-pound wheeled unit. The wheeled unit weight was 70 pounds at 0 lb/in². The storage tank pressure was approximately 10 lb/in². The weight of halon transferred as a function of time is shown on the following page.

Halon transfer

Pumping time	Halon transferred, lb
45 s	25
1 min 30 s	50
2 min 25 s	75
3 min 26 s	100
4 min 37 s	125
5 min 59 s	150

The final weight of the wheeled unit was 220 pounds. The average halon transfer rate for this test was 25 lb/min.

B. NINE-POUND HAND UNIT--TRANSFER (T) AND RECOVERY (R)

TEST BT-1. The system was connected to pump from a 9-pound hand unit into a storage tank. After pumping for 1 minute, only 0.5 pound of halon remained in the unit.

TEST BT-2. The system was connected from a full 9-pound hand unit to a recovery tank. The hand unit was pressurized to 195 lb/in² and had a total weight of 15.5 pounds. The recovery tank pressure was 38 lb/in². After pumping for 25 seconds, the unit weight was reduced to 6 pounds, 4 ounces.

TEST BT-3. The system was connected from a 9-pound hand unit to a recovery tank. The hand unit weighed 15.5 pounds and was at 30 lb/in². No nitrogen was added. The system was switched on, and the unit was rocked back and forth to keep the dip tube in contact with the liquid. After 52 seconds of pumping, the weight of the unit was reduced to 6 pounds, 12 ounces. A longer pumping time was required because the nitrogen pressure was discharged prior to starting the test.

TEST BT-4. The system was connected from a 9-pound hand unit to a storage tank. The total initial weight of the hand unit was 15 pounds at 195 lb/in². After 26 seconds of pumping the unit weight was reduced to 6 pounds, 8 ounces.

TEST BR-1. The input line of the system was connected to the liquid line of a 200-pound supply cylinder, and the outlet line of the system was connected to a 9-pound hand unit. The system transferred 9 pounds of halon into the hand unit in 18 seconds. Upon completion of this test, a check valve was installed in the output line of the system to improve the operation of the pump. The transfer test was repeated and the fill time decreased from 18 seconds to 16 seconds.

TEST BR-2. The same 9-pound hand unit used in the previous test was used, and the procedure was reversed. The system was connected to pump from the storage tank into the hand unit. The system was turned on, and the unit was filled in 1 minute to the specified weight of 16 pounds.

TEST BR-3. The system was connected from a storage cylinder to a 9-pound hand unit. The pressure in the storage cylinder was 38 lb/in². The hand unit weighed 5 pounds, 12 ounces with a pressure of 0 lb/in². The system was turned on, and the unit was charged to 15.5 pounds in 44 seconds.

TEST BR-4. The system was connected to pump from the storage tank into the hand unit, having an initial weight of 5 pounds and a pressure of 0 lb/in². The unit was charged to 15 pounds and 10 ounces after pumping for 26 seconds. Standing the unit upright allowed the liquid from the filter to go down to the pump. This seemed to help the pump remain primed; however, little increase in system performance was observed.

C. P-19--TRANSFER (T) AND RECOVERY (R)

TEST CT-1. The system was connected to pump from the bottom of a P-19 tank to the vapor dome of a 1500-pound storage cylinder. The system was started. When approximately one-half of the liquid halon was recovered from the P-19 system, the system stopped transferring halon. The failure at this point could have been due to increased pressure in the 1500-pound storage cylinder. The increase in pressure could have resulted from halon vaporization owing to the high outside temperature of 99.5 °F.

TEST CT-2. The recovery system was connected to pump from the bottom of the P-19 system to the liquid line (dip tube) of a 1500-pound cylinder. A vapor line was connected between the vapor dome of both tanks. The system was turned on, and after 12 minutes and 52 seconds, all the liquid halon was removed from the P-19 tank.

TEST CR-1. The system was connected to pump from a 1500-pound storage cylinder into the bottom of the P-19 halon tank. The system was started. After 21 minutes and 15 seconds the P-19 halon tank was only half full. At this point the hose was disconnected from the bottom of the P-19 tank and connected to the top of the tank. The system was restarted. The transfer rate seemed to remain the same.

D. HOSE COMPATABILITY AND TRANSFER TESTS

TEST D-1. A fully charged 150-pound wheeled fire extinguisher was used to determine the deterioration of hose material after exposure to Halon 1211. The halon was discharged through the outlet nozzle until liquid halon was present. Both the nozzle valve and extinguisher valves were closed to trap halon in the hose under full system pressure (150 lb/in²). The 50-foot hose was 3/4-inch ID Dayton 7198. The outside temperature was 98 °F.

This test was used to determine the feasibility of recovering and filtering halon left in a hose after an extinguisher is used but not fully discharged. Residue from a new, unused hose is greater than that normally found after a hose has been exposed to halon. The residue from a hose could plug the filter-drier.

After 24 hours of exposure to halon no swelling, blistering, or bulging of the hose was observed. The contents of the hose were expelled into a clean container by opening the nozzle valve and "walking" the hose hand-over-head. The total weight of the contents was 1426 grams 1 minute after being expelled into the container. The contents were light yellow and appeared to be primarily liquid halon. Only a small amount of residue remained after evaporation. The residue appeared to contain rubber, indicating that it was elastic fiber from the inside wall of the new hoses.

Both ends of the hose and the entire outside of the hose were carefully checked for deterioration. No deterioration or damage was observed.

The hose was recharged with liquid halon and left under pressure for another 24 hours. No damage to the hose was observed. The hose was left charged with liquid halon for an additional 48 hours and the contents from the hose were then emptied into a clean container. The halon was only slightly discolored. No damage to the hose was observed. The total exposure time of the hose to halon was 96 hours.

TEST D-2. The hose of a 150-pound wheeled unit was filled with halon. Approximately 14 pounds of liquid halon were required. The system was connected to pump from the hose into a recovery tank. The system was turned on and the hose was "walked" out using the hand-over-head method. After 2.5 minutes of pumping, the system was turned off and disconnected from the hose. The contents of the hose were discharged into a clean container. It was estimated that less than 1 percent of the halon initially contained in the hose remained.

TEST D-3. The P-19 system hose was charged with liquid halon. The system was connected to pump from the hose into a 1500-pound storage cylinder. The system was switched on, and the hose was walked out by the hand-over-head method. After 2 minutes of pumping only a small amount (estimated to be less than 1 percent) of halon remained in the hose.

E. RECIRCULATION TESTS

TEST E-1. A 45-gallon storage tank was filled with 150 pounds of Halon 1211. The discharge line of the system was connected to the vapor line of the tank, and the inlet line of the system was connected to the liquid line of the storage tank. The operating inlet pressure of the system was 25 lb/in²; the outlet pressure was 45 lb/in². The total system operating time for this test was 4 hours.

TEST E-2. The inlet line of the system was connected to the liquid line at the bottom of the tank, and the outlet line of the system was connected to the vapor line at the top of the tank. The system was allowed to

operate for 4 hours. The See-All indicator changed to a greener color by the end of the test. This indicated that moisture had been removed from the halon during the test.

F. TEST DATA AND NOTES

1. To determine why halon remained in the wheeled unit after the early recovery operations, the dip tube was removed, inspected, and measured. The dip tube enters the top of the extinguisher near the side and angles down through the tank to a point approximately 1/2 inch from the opposite inside tank wall. See Figure 1 for details.

2. Extinguisher Halon Transfer and Recovery Test: Each test was repeated a minimum of eight times, achieving the same or similar results. A total of 208 tests were conducted.

3. Extinguisher Hose and Halon Compatability Test: A series of tests conducted at different exposure periods was performed to evaluate and determine the effect of Halon 1211 on extinguisher hose. The total test time was 96 hours.

4. Extinguisher Hose Evacuation Test on the P-19 Fire Truck System and 150-Pound Wheeled Unit: This test was repeated a total of six times with three tests for each extinguisher system. The same or similar results were achieved.

5. Recovery Test on the P-19 Fire Vehicle: Each test was repeated a total of three times, all achieving the same or similar results. A total of nine tests were conducted.

6. Transfer Test for the P-19 Fire Vehicle: Each test was repeated a total of four times. The same or similar results were achieved during these tests. A total of eight tests were conducted.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. The prototype system is well-designed but fails to have the pumping capability necessary to meet the desired requirements. The halon transfer rate in this type of pumping system is affected by the inlet supply to the system. Restrictions from the dip tube of a 1500-pound supply cylinder through the small 3/8-inch opening in the discharge valve on the tank, cause a pressure drop, resulting in vaporization of halon which greatly reduces the pump efficiency.

2. Presently used extinguisher and storage cylinders are not configured for efficient and rapid transfer of halon between vessels. Some procedural and configuration changes are required as discussed below. These recommended changes are neither costly nor detrimental to firefighting operations.

B. RECOMMENDATIONS

A purchase description has been developed and is contained in Appendix A. A recycle/recovery system is described which will effectively transfer Halon 1211 between pressure vessels while simultaneously removing moisture and other contaminants from the halon agent. Air Force implementation of this purchase description will produce a system which will effect a savings for all military services in agent replacement. Implementation of this system will also reduce halon emissions to the atmosphere during transfer and maintenance operations. The following recommendations are made.

1. A pump with an increased capacity should be used. The pump should be of the type and size needed to transfer Halon 1211 between a truck-mounted or portable extinguisher unit and a storage container at a rate of not less than 3 gal/min against an outlet gage pressure of 200 lb/in². The pump should also be able to develop a minimum vacuum of 12 inches of mercury under conditions of no inlet flow.

2. To ensure a full supply of liquid halon to the pump, it is essential that the halon being transferred be removed from the bottom of a 1500-pound storage tank. To accomplish this it will be necessary to invert the storage cylinder on a locally manufactured stand and connect the input line of the transfer system to the vapor valve on the storage cylinder.

As an option to eliminate the requirement of inverting the 1500-pound storage cylinder, a redesigned halon storage tank could be used. The storage tank should have a minimum capacity of 500 pounds at a maximum fill ratio of 85 percent at 70 °F and include properly sized inlet and outlet valves, pressure gage, pressure relief valves, and agent level gage. The tank could be cylindrical, positioned with its axis horizontal or vertical, and mounted on a wheeled support system.

3. When possible, a hose should be connected between the vapor dome of the supply and receiver tanks in order for the pressure to equalize between the tanks during servicing operations. When it is impractical to use a vapor line, it may be necessary to install a vacuum breaker connected to the vapor dome of the supply cylinder. The installation of a vacuum breaker will ensure positive evacuation of the halon and prevent back siphoning during transfer operations. It is recommended that a vacuum breaker set to open at 1.5 inches of mercury be considered for this application.

4. When long sections of extinguisher hose are evacuated in a closed system, it may be necessary to install a vacuum breaker on the extinguisher system. The breaker should be installed as a modification to the system and connected on the discharge side of the main halon discharge valve at or ahead of the hose connection. This will ensure positive evacuation of the hose and prevent back siphoning during evacuation. It is recommended that a vacuum breaker set to open at 1.5 inches of mercury be considered for this application.

REFERENCES

1. Walker, F.K., **Air Force Fire Protection Halon Usage, CURRENT THROUGH 1995**, Report Prepared for HQ USAF/LEEEU and maintained on file, Bolling AFB, DC, 20332, 1986.
2. Plugge, M.A., Tapscott, R.E., Beeson, H.D., and Zallen, D.M., **Fire Suppression by Halon 2402**, Volume I and II, ESL-TR-86-60, Engineering and Services Laboratory, Air Force Engineering and Services Center, Tyndall AFB, Florida, June 1986.
3. **Sporlan Bulletin 40-10**, "Catch-All Liquid Line and Suction Line Filter-Driers," 1 August 1984.
4. **Sporlan Bulletin 70-10**, "See-All, a Combination Moisture and Liquid Indicator for Use on 12-22-505 and Other Refrigerants," October 1986.

BIBLIOGRAPHY

Handbook of Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Incorporated.

Horvath, A.L., **Halogenated Hydrocarbons, Solubility - Miscibility with Water**, Marcel Dekker Inc., New York, 1982.

ICI Imperial Chemical, **B.C.F. (Halon 1211) Systems Design Manual**.

Kent's Mechanical Engineers Handbook, Design and Production, 11th Edition, 1936-1938.

National Electric Code, NFPA 70, National Fire Protection Association, 1984.

Stoecker, W.E., and Jones, I.W., **Refrigeration and Air-Conditioning**, McGraw-Hill, Inc., 2nd Edition, 1982.

Uniform Mechanical Code, International Conference of Building Officials and International Association of Plumbing and Mechanical Officials.

Uniform Plumbing Code, International Association of Plumbing and Mechanical Officials, 1982.

APPENDIX A
DRAFT PURCHASE DESCRIPTION,
RECHARGE/RECOVERY UNIT FOR BROMOCHLORODIFLUOROMETHANE

1. SCOPE

1.1 Purpose. This purchase description covers the requirements for a bromochlorodifluoromethane (Halon 1211) recharge/recovery unit which is capable of transferring Halon 1211 between pressure vessels while simultaneously removing moisture and other contaminants from the halon.

2. APPLICABLE DOCUMENTS

2.1 Government documents. The following documents, of the issues in effect on the date of invitation for bid or request for proposal, form a part of this description to the extent specified herein.

(a) Specifications, Military

MIL-P-116	Preservation-Packaging, Methods of
MIL-B-38741	Bromochlorodifluoromethane, Technical
MIL-B-26195	Boxes, Wood-Cleated, Skidded, Load-Bearing Base

(b) Standards, Military

MIL-STD-100	Engineering Drawings and Practices
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-831	Test Reports, Preparation of
MIL-STD-889	Dissimilar Metals
MIL-STD-1186	Cushioning, Anchoring, Bracing, Blocking and Waterproofing; with Appropriate Test Methods

(Copies of specifications, standards, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Preproduction. This purchase description makes provisions for preproduction testing.

3.2 Description. The recharge/recovery system (referred to as the "system") described herein provides the capability of transferring Halon 1211 between pressure vessels while simultaneously removing contaminants. The purpose of this system is to eliminate losses of Halon 1211 into the atmosphere. The system is required to operate in three modes: (1) Recharge mode, where Halon 1211 is transferred from a bulk storage container into an extinguisher unit. (2) Recovery mode, where Halon 1211 is transferred from an extinguisher, handline, or other pressure vessel into a bulk storage container. (3) Recirculation mode, where Halon 1211 is recirculated from a storage container or an extinguisher unit through the system to assure halon quality. The system shall include and shall be mounted on a wheeled device similar to a small furniture dolly. The system components shall be housed in a metal enclosure and attached to the front lower portion of the dolly. The enclosure shall be approximately 24 inches wide, 30 inches high, and 16 inches deep. The pressure and moisture indicator gages shall be mounted in a visible location on the external surface of the enclosure. The front of the dolly above the enclosure shall be fitted with extended arms to secure the transfer hose and power cord to the system. The system shall contain the following major function components.

<u>Item Name</u>	<u>Requirement</u>
Pump Unit	3.4.3
Filter Unit	3.4.4
Meter	3.4.5

3.3 System Requirements. The following requirements shall apply to the recharge/recovery system as specified herein.

3.3.1 Materials. Materials shall be as specified herein. Materials not specifically covered by this or applicable specifications shall be suitable in every respect and of good quality. Wood shall not be used in construction.

3.3.1.1 Metals. Unless otherwise specified herein, metal components of the systems in contact with the agent shall be compatible with Halon 1211. Unless protected against electrolytic corrosion, dissimilar metals shall not be used in intimate contact with each other. Dissimilar metals are defined in MIL-STD-889.

3.3.1.2 Non-metals. Non-metal components of the system in contact with the agent shall be compatible with Halon 1211.

3.3.2 Design and construction. The system shall be so designed and constructed that parts will not work loose in service. It shall be inherently capable of withstanding the stresses, jars, vibrations, and other conditions incident to shipping, storage, and usage, and shall provide maximum ease and safety of operation. All controls and installed equipment shall be located so there is no interference with each other, or with the operation, and shall be readily accessible for maintenance, operation, and replacement. All loose parts such as pins or protective caps shall be securely attached so they can not become separated from the unit. The system shall be equipped with safety devices to adequately protect all hazards incident to their operation.

3.3.2.1 Functional design. The system shall be designed to operate efficiently. Meters, gages, and switches shall be accessible or readable from a standing position. Storage for hoses and fittings shall be provided as an integral part of the system. The system shall be designed to be portable. The flow of the agent through the system shall be as described in Figure A-1, to include a valving arrangement to accomodate bidirectional flow selection.

3.3.2.2 Reliability. The reliability of the system to satisfy its intended use will be demonstrated by the successful completion of the tests specified herein.

3.3.2.3 Maintainability. The system shall be designed and constructed to provide:

- (a) A minimum number of parts consistent with performances herein.

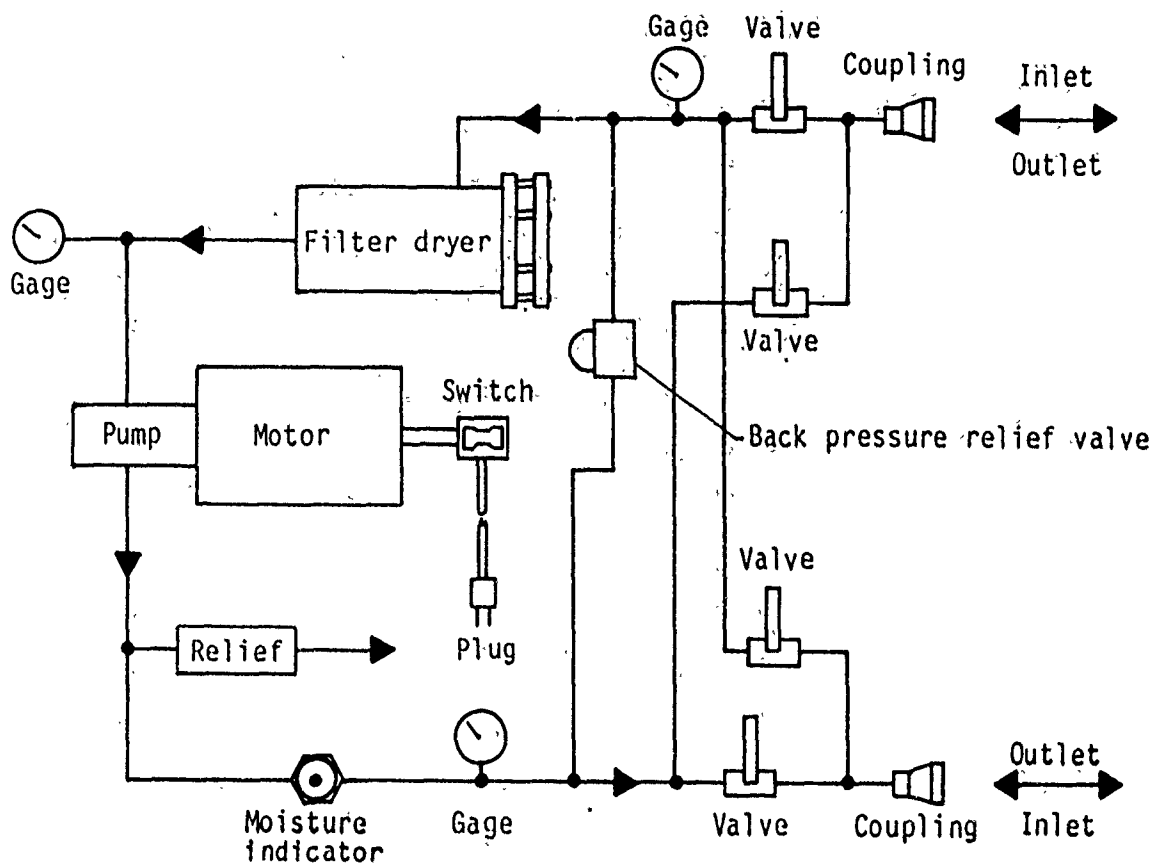


Figure A-1. Halon 1211 Recovery/Charging System.

- (b) Parts and components that are located or positioned for ease of inspection and recognition of excessive wear or potential failure.
- (c) Ease of adjusting, servicing, and replacing parts and components.
- (d) Use of readily available standard tools and equipment for maintenance.
- (e) Maintenance with a minimum number of tools.

3.3.3 Pump unit. The pump unit shall be of sufficient type and size to transfer Halon 1211 between truck-mounted or portable extinguisher unit and storage vessel at a rate not less than 2.7 gallons per minute at 70 °F against a head pressure of 150 lb/in² as demonstrated by the successful completion of the test specified herein. The pump unit shall be capable of developing a minimum vacuum of 5 inches of mercury under conditions of no inlet flow and of running dry without damage to the pump. The pump motor shall be of all-weather construction. A weatherproof motor switch shall be provided with a 15-foot, grounded electrical cord. The system shall be capable of operating at variable power and cycle settings, i.e., 115 volts, 60 cycles; 220 volts, 50 cycles, etc. Note: These systems will be used world-wide; therefore, variable current cycles are required. The specific requirements shall be determined by the procuring agency.

3.3.3.1 Compatibility. The pump components in contact with the agent shall be compatible with Halon 1211.

3.3.3.2 Bypass. The pump unit shall be equipped with a bypass to the suction side to prevent the overpressurization of the pump extinguisher or storage cylinder. The bypass shall be of sufficient type and size that it bypasses the full flow of the pump at 260 lb/in² maximum and closes at a pressure not less than 210 lb/in². The bypass pressure shall not increase as a result of pressure on the downstream side of the bypass.

3.3.4 Filter unit. The filter unit shall consist of a steel shell and a replaceable filter cartridge core. Multiple cartridges may be required to allow for sufficient surface area for filtration. The core shall attach to an end plate which shall be accessible for ease of servicing and replacement

of cartridges. The cartridges shall seat in the shell by means of mechanical seats or gaskets so as to prevent bypassing of the halon around the cartridge during filtration. The effectiveness of the filter unit shall be demonstrated by the successful completion of tests described herein.

3.3.4.1 Filter shell. The steel shell shall be of sufficient size and type to allow for the flow of halon through the system without significant pressure drop. In addition, the steel shell shall be of sufficient size and type to allow for a sufficient surface area for filtration. The filter shell shall have as a minimum a working pressure of 500 lb/in².

3.3.4.2 Filter cartridge. The filter cartridge shall be composed of desiccants, activated alumina, and molecular sieves, and molded in such a way as to create uniform porosity throughout the entire surface of the core. The filter cartridge shall be capable of removing oils, acids, particulate matter, and moisture. Sufficient cartridges shall be incorporated into the filter unit to yield a volume of desiccant equivalent to 96 in³.

3.3.5 Meter. The meter shall be an in-line moisture and liquid indicator. The meter shall clearly indicate the moisture content of the halon by a color indication caused by flow of the halon over a filter disk impregnated with a chemical salt. The color change shall be reversible and shall indicate that the halon is dry below approximately 30 p/m and wet above approximately 70 p/m, with the intermittent region showing caution. The indicator element shall be replaceable without removing the meter from the line. The meter shall also incorporate a sight glass to give an indication of the liquid level and clarity of the halon after filtration. The meter shall be of sufficient size that it does not cause any significant restriction of flow. The meter shall have a safe working pressure of 500 lb/in² minimum. A calibrated color template shall be provided by the meter supplier and placed on the meter or adjacent to the meter.

3.3.6 Associated plumbing. All plumbing and valves used to connect the pump, filter, and meter shall be compatible with Halon 1211, and shall be of sufficient size and type so as to not restrict the flow of the halon or cause an excessive pressure drop through the system. Additionally all plumbing and valves (except the system pressure relief valve, 3.3.8) shall

have a minimum safe working pressure rating of 500 lb/in². Valves shall be color coded and flow direction shall be indicated at appropriate locations.

3.3.7 Hoses and fittings. All hoses and fittings used to connect the system to the various pressure vessels shall be of sufficient size and type so as to not cause an excessive pressure drop through the system. All hoses and fittings shall be compatible with Halon 1211 and have a minimum safe working pressure rating of 500 lb/in².

3.3.7.1 Hoses and hose storage. All hoses used to connect the system to the various pressure vessels shall be of sufficient length (20 feet minimum) and flexibility to allow for simple and convenient operation of the system. The hoses shall be constructed of material that is compatible with Halon 1211, and resistant to the effects of Halon 1211 when stored under pressure, as demonstrated by the successful completion of tests described herein. The hoses shall connect to various fittings attached to extinguisher units and pressure vessels through the use of double-end shut-off quick-disconnects. Sufficient markings shall be on the hoses to indicate direction of flow when connecting the system. In order to have a closed loop system and permit the pressure to equalize between the extinguisher and pressure vessels, a hose 30 feet in length, meeting the specifications described herein, shall be provided to connect between the vapor dome of the extinguisher unit and the pressure vessel. A means shall be provided for convenient storage of the hoses, adapters, and extension cord when not in use or when the system is being relocated.

3.3.7.2 Fittings. Sufficient fittings of proper thread size and type shall be supplied with the system to allow the system to be connected to any Halon 1211 handheld extinguisher, wheeled extinguisher, truck-mounted extinguishing system, or storage cylinder in inventory to satisfy the intended use of the system. Additionally, fittings shall be supplied to allow halon to be recovered from a charged handline on a wheeled unit or truck-mounted unit and placed either into a storage cylinder or into the extinguisher unit. The fittings shall connect to the hoses of the system through the use of double-end shut-off quick-connects. The fittings shall have a minimum safe working pressure of 500 lb/in².

3.3.8 System pressure relief. The system shall be equipped with a spring-loaded pressure relief set to open at 350 lb/in² and close at a pressure not less than 300 lb/in². The relief valve shall incorporate features that will preclude tampering with the pressure relief setting.

3.3.9 Electrical requirements. The system shall be capable of operating using 115 VAC variable power and cycle settings, i.e., 60-cycle; 220-volt, 50-cycle (Ref 3.3.3).

3.3.10 Pressure gages. Pressure gages shall be installed to indicate the inlet and outlet pressure for the system. These gages shall be capable of determining the pressure to within 5 lb/in². A pressure gage shall also be installed to measure the differential pressure drop across the filter. This pressure gage shall be capable of determining the pressure to within 1 lb/in². All pressure gages shall be compatible with both liquid and gaseous Halon 1211 and have a sufficient range so as to be applicable over the entire working pressure range of the system. The manufacturer shall establish a pressure drop standard to indicate when the filter requires changing. The gages shall be unobstructed and easily visible. Pressure gages shall have a shatterproof gage dial and window.

3.4 Documentation. The system shall be supplied with a complete operation and maintenance procedures manual which will give clear and concise instructions to those personnel using the system on the proper operation and maintenance of the system to satisfy its intended use. The manual shall include drawings, photographs, and procedures to permit firefighters and mechanical service personnel to operate the system and to perform all maintenance and repair. The manual shall include a section to permit troubleshooting to identify and correct malfunctions. The manual shall also contain a complete parts list. Drawings associated with documentation shall be in accordance with MIL-STD-100. Additionally, a video presentation (15 minutes minimum, professional quality with voice) shall be provided which teaches personnel to operate, maintain, and repair the system.

3.5 Markings.

3.5.1 Identification of product. Equipment, assemblies, and parts shall be marked in accordance with MIL-STD-130.

3.6 Workmanship. The recharge/recovery system, including all parts and accessories, shall be fabricated and finished in a thoroughly workman-like manner. Particular attention shall be given to freedom from blemishes, defects, burrs, and sharp edges; marking of parts and assemblies; thoroughness of soldering, welding, brazing, riveting, and painting; alignment of parts; and tightness of assembly screws, bolts, etc.

3.7 System performance. The performance requirements of the system shall be based on operation from -0 to +125 °F temperatures. The unit shall perform as specified herein when subjected to relative humidities up to 100 percent, and exposure to rain and salt fog environments.

3.7.1 Recharge. The system shall be capable of accurately and effectively recharging any Halon 1211 handheld fire extinguisher, wheeled extinguisher, or truck-mounted extinguisher unit in inventory with Halon 1211 supplied from a normal supply cylinder. The system shall have a capacity sufficient to recharge the Halon 1211 system on the P-19 crash fire vehicle in 10 minutes. The system shall also be able to charge a 9-pound handheld extinguisher within the pressure tolerances specified for that extinguisher.

3.7.2 Recovery. The system shall be capable of effectively recovering the Halon 1211 from any truck-, skid-, or wheeled-mounted extinguisher or handheld unit presently in inventory by transferring the halon from the extinguisher unit into a standard storage cylinder. Specific requirements are that the system: (1) recover the halon from any 500-pound truck-mounted system within 25 minutes without the assistance of nitrogen pressurization, and with a recovery efficiency as described in 4.6.7 of 0.98, (2) recover the halon from any handheld or wheeled extinguisher unit without venting the extinguisher pressure to the atmosphere, and with a recovery efficiency as described in 4.6.7 of 0.98, and (3) recover the Halon 1211 pressurization, or a truck-mounted unit charged with halon, without the assistance of nitrogen pressurization, and with a recovery efficiency greater than 0.90.

3.7.3 Recirculation. The system shall be capable of continuously recirculating Halon 1211 in a storage cylinder to filter and dry the halon. The system shall be capable of recirculating the entire volume of a 1500-pound supply cylinder of halon in 60 minutes while indicating the moisture content of the halon in the cylinder. Additionally, the system shall be capable of recirculating the entire volume of a 500-pound truck-mounted system in 45 minutes and be able to indicate the moisture content of the halon during recirculation.

3.7.4 System leakage. The system shall not exhibit agent leakage rates exceeding the following.

- (a) Welded seams and soldered seams in piping or components--
1 ounce per year each seam.
- (b) Threaded connections--5 ounces per year each connection.
- (c) Valves, gages, and pump--5 ounces per year each valve,
gage, or pump.

3.8 Warranty. The manufacturer/supplier shall provide a minimum 5-year warranty on all system components.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or other facilities suitable for the performance of inspection requirements specified herein, and approved by the Government. The Government reserves the right to perform any inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements. Inspection records of the examinations and tests shall be kept complete and available to the government upon request.

4.2 Classification of tests. The inspection and testing of the system shall be classified as follows:

- (a) Preproduction testing, see 4.4.
- (b) Quality conformance tests, see 4.5.

4.3 Test conditions.

4.3.1 Preparation for test. All systems submitted for test shall contain all specified components and shall be completely assembled and properly adjusted and serviced for immediate operation.

4.3.2 Test agent. The test agent shall be bromochlorodifluoromethane (Halon 1211) conforming to the requirements of MIL-B-38741.

4.3.3 Test data. During the tests specified herein, at least the following data, as applicable, shall be collected at time intervals dictated by the test objective.

- (a) Time started
- (b) Time completed
- (c) Ambient temperature
- (d) Inlet pressure
- (e) Outlet pressure
- (f) Running time of pump unit
- (g) Cumulative running time of pump unit
- (h) Quantity of agent transferred

4.3.4 Test observations. Throughout all tests specified herein, the system shall be closely observed for the following conditions which shall be considered cause for rejection.

- (a) Failure to conform to design and performance requirements specified herein.
- (b) Undue spillage or leakage of agent.
- (c) Erratic agent flow caused by pump cavitation or failure.
- (d) Excessive heating of electrical connections or equipment.

- (e) Running time of pump unit
- (f) Excessive cumulative running time of pump unit
- (g) Insufficient quantity of agent transferred

4.4 Preproduction testing. (Also see 6.2.)

4.4.1 Test sample. One system shall be subjected to the tests specified in 4.4.3.

4.4.2 Test report. After completion of the preproduction tests, a test report shall be prepared in accordance with MIL-STD-831. The report shall cover each test required under a separate section or paragraph which in turn shall list individual tests purposes or objectives; describe procedures followed in each individual test; and compare by means of a checklist and table (as applicable) test results with the respective performance or design requirements for which the test is intended to demonstrate compliance.

4.4.2.1 Reliability and maintainability information. The following information shall be included as an appendix to the test report.

- (a) All failures, servicing, adjustments, maintenance, and irregular functioning shall be identified by accumulated operating time, cycles, or position in the test procedure, as appropriate. Test conditions at the time of the events identified shall be recorded.
- (b) Test operator and maintenance technician actions, test equipment and test facility failures, and other events that might serve as grounds for a request that an equipment failure not be counted as a reliability failure. Detailed descriptions of the events and the analysis to substantiate any such request shall be included and shall be clearly cross-referenced to each applicable failure.
- (c) A summary of the engineering analysis and of any tests conducted to determine assignable causes for any failure or irregular functioning.

- (d) A summary of the engineering analysis leading to any corrections made to design, construction, quality control, or other procedures, or leading to any corrections to be made or proposed to be made to production items. The summary shall also include an analysis of the predicted effectiveness of such corrections. Failures that have been corrected by design changes or by other means shall be counted as reliability failures until the corrections have been both analyzed and verified by test sufficiently to substantiate the effectiveness of the correction to the satisfaction of the procuring activity.
- (e) Clock time and man-hours required for each maintenance and servicing action taken during the tests. Only the time needed for actually preparing for and performing the tasks shall be measured and recorded. A brief description of experience and qualifications of the personnel taking such actions.

4.5 Quality conformance tests. Each delivery system shall be subjected to the following tests as described under 4.6.

- (a) Examination of product, see 4.6.1.
- (b) Mechanical inspection, see 4.6.2.
- (c) Leakage, see 4.6.3.
- (d) Relief valve, see 4.6.4.

4.5.1 Rejection and retest. When an item tested fails to meet the specification, items still on hand or later produced shall not be accepted until the extent and cause of failure have been determined and appropriately corrected. The contractor shall explain to the Government representative the cause of the failure and the action taken to preclude recurrence. After correction all tests shall be repeated. Final acceptance of the items on hand or produced later shall not be made until it is determined that all items meet all the requirements of the specification.

4.6 Test methods.

4.6.1 Examination of product. The system shall be inspected to determine compliance with requirements of this description with respect to materials, finishes, markings, workmanship, and installation of components.

4.6.2 Mechanical inspection. A critical inspection shall be made of the agent delivery system and all components including fastening devices, data plates, valves, gages, piping, hose, operating controls, etc., and data recorded as to their condition, defects in manufacture, damage in transit, and damage through use prior to test.

4.6.3 Leakage. The system shall be filled with halon by following the supplier's directions for recirculation and uncoupling the quick-connects with the system full. The filled system shall be subjected to an ambient temperature of not less than 70 °F for a period of not less than 24 hours. At the end of the 24-hour period, a Halogen Leak Detector, such as the GE Type H-25, shall be used to determine the leakage rate at all seams and all threaded connections around the gages, pump, and valves.

4.6.4 Relief valve. Prior to installation on the system, the spring-loaded relief valve shall be subjected to a gradually increasing pressure of clean, dry, oil-free air or nitrogen at its inlet until it starts to discharge. The relief valve should be set to fully open at 350 lb/in² and close at a pressure not less than 300 lb/in². The pressure then shall be reduced until the valve completely reseals. This procedure shall be repeated not less than two times. Following the test, the valve shall be checked for leakage by application of a soap film (film across the outlet and over all outside surfaces) with not less than the maximum working pressure of the component which the valve will be used to protect being applied at the valve inlet. Failure to open and reseal within the specific limits or an indication of leakage during soap film test shall be recorded.

4.6.5 Filter efficiency. The efficiency of moisture removal by the filter unit shall be determined by passing Halon 1211 at a known moisture content through the filter and then analyzing the recovered halon for moisture content.

4.6.5.1 Procedure. Following the procedure contained in MIL-B-38741 the moisture content of a sufficient quantity of Halon 1211 shall be determined and that halon shall be used to fill a 20-pound handheld extinguisher. The extinguisher shall not be pressurized. The extinguisher shall then be cooled to approximately -15 °C and sufficient water added to bring the total water content of the halon to 80 p/m. The extinguisher shall then be allowed to warm to room temperature. The extinguisher shall then be pressurized using dry nitrogen the halon shall be and transferred through the filter to a clean and dry extinguisher unit. The recovered halon shall then be analyzed for water content according to the procedures outlined in MIL-B-38741, and the filter efficiency calculated based on the results. A filter efficiency of greater than 0.63 shall be considered satisfactory.

4.6.5.2 Calculations. The filter efficiency shall be calculated as follows.

$$\text{filter efficiency} = \frac{80 - C_f}{80} \quad (A-1)$$

where

C = the final water content determined after filtration in parts per million.

4.6.6 Recharge tests. Following the instructions for operation of the system provided by the supplier, the ability of the unit to recharge a 9-pound handheld extinguisher, a 150-pound wheeled extinguisher, and the halon system on a P-19 crash fire vehicle shall be demonstrated. The performance of the system shall be compared against the requirements in 3.7.1.

4.6.7 Recovery tests. Following the instructions for operation of the system provided by the supplier, the ability of the unit to recover halon from a charged 9-pound handheld extinguisher, a charged 150-pound wheeled extinguisher, a charged handline on a P-19 crash fire vehicle, and the halon system on a P-19 crash fire vehicle shall be demonstrated. The performance of the system shall be compared to the requirements given in 3.7.2.

4.6.7.1 Recovery efficiency. The recovery efficiency shall be obtained by recording the weight of halon in the container being recovered and the actual weight recovered by the system and calculated as follows:

$$\text{Recovery efficiency} = \frac{W_t}{W_c} \quad (\text{A-2})$$

where

W_t = the weight of agent transferred by the system in pounds;
 W_c = the weight of agent in the container to be transferred in pounds.

4.6.8 Recirculation tests. Following the instructions for operation of the system provided by the supplier, the ability of the unit to recirculate the contents of a 1500-pound storage cylinder and the halon system on a P-19 crash fire vehicle shall be demonstrated. The pump flow rate shall be measured by installing a flow meter after the moisture indicator. The flow rate shall be sufficient to meet the requirements of 3.7.3. At the time specified in 3.7.3 the moisture content shall be observed using the moisture indicator and recorded. The recirculation shall continue for another 2 time periods after which the moisture content shall again be recorded and any differences in indication noted.

4.6.9 Pump durability. The durability of the pump shall be demonstrated by recirculating Halon 1211 in a 1500-pound storage cylinder against a pressure differential of 50 lb/in² for a continuous period of 200 hours.

4.6.9.1 Procedure. A spring-loaded liquid check valve which is compatible with Halon 1211 and set to open to full flow at 100 lb/in² and close at 50 lb/in² shall be installed in the system after the moisture indicator. The system shall be configured according to the instructions for operation provided by the supplier for recirculation, and the system allowed to operate in the recirculation mode for a period of 200 hours continuous running time on the pump. After the completion of the test the pump shall be examined for excessive wear.

4.6.10 Hose compatibility. The compatibility of the transfer hose with Halon 1211 shall be determined by filling the system with halon following the procedure outlined in 4.6.3 and allowing the system to stand full for 200 hours at an ambient temperature of not less than 70 °F. After the 200 hours, the system shall be emptied of halon and the hose material examined thoroughly for signs of degradation (loss of flexibility, cracking, swelling, etc.).

4.7 Inspection of preparation for delivery. Preservation, packaging, packing, and marking for shipment and storage shall be inspected to determine conformance to the requirements of Section 5.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging. Preservation and packaging shall be level A or C as specified.

5.1.1 Level A. The system shall be prepared according to Method III, MIL-P-116. Components shall be adequately secured to prevent movement and damage in accordance with MIL-STD-1186 and good commercial practice to prevent damage during shipping, handling, and storage.

5.1.2 Level C. Level C shall be the same as level A except the containers may be fiberboard of sufficient strength and the barrier material and tape need not be waterproof.

5.2 Packing. Packing shall be Level A or C as specified. Should Level B be specified, Level A shall apply.

5.2.1 Level A. Each system shall be packed within a container conforming to Type II, Style A, Class 1 plywood superstructure MIL-B-26195. The system shall be secured to the container base in accordance with MIL-STD-1186.

5.2.2 Level C. Each system shall be packed within a container conforming to Type I, Style C, Class 1 fiberboard superstructure Mil-B-26195. The system shall be secured to the container base in accordance with MIL-STD-1186.

5.3 Markings. Marking for shipment and storage shall be in accordance with MIL-STD-129.

6. NOTES

6.1 Intended use. The intended use of the recharge/recovery system specified herein is to transfer Halon 1211 between pressure vessels while simultaneously removing contaminants and minimizing the loss of halon associated with such transfers.

6.2 Ordering data. Procurement documents should specify the following:

- (a) Title, number, and date of this description.
- (b) Location and conditions for preproduction testing (see 4.4).
- (c) Level of preservation and packaging required (see 5.1).
- (d) Level of packing required (see 5.2).
- (e) Additional markings if required (see 5.3).

APPENDIX B

PRODUCTION AND LIFE-CYCLE COST ANALYSIS

The production and life-cycle cost analysis is provided on the format data sheet (Figure B-1) in accordance with current Air Force directives. Total life-cycle costs are based on an expected 10-year life of the system. It must be noted that the costs depicted here are those of the specific system and subsystems tested under this project. Because the performance specification is written to provide prospective bidders/suppliers with the latitude to select other subsystem components, such bidders/suppliers should be required to also provide these data on their particular systems.

Unit of Measure: EA
 Classification: 1

Labor Category: E
 Life Expectancy: 10 yr

Frequency Codes:
 W - Weekly
 BW - Bi-Weekly
 M - Monthly
 BM - Bi-Monthly

0 - Quarterly
 A - Annual
 SA - Semi-Annual
 O - Other

O & M Activities	Frequency	Volt	MHs	Material \$/%	Equipment \$
Recurring/Preventive Maintenance (labor cost est. at \$15.00-per MH)					
Filter Core Replacement	SA	EA (1)	15.00	80.00	0.0
Moisture Indicator Kit Replacement	A	EA (0.5)	7.50	24.00	0.0
System Ops. Check	M	EA (1)	15.00	0.0	0.0
Annual Parts Replacement	A		0.0	104.00	0.0
Annual Labor Cost	A		37.50	0.0	0.0
TOTAL ANNUAL O & M COST				\$141.50	

LOGISTICS SUPPORT:

Training--to be conducted at home station.
 Operating and Maintenance Manual--provided with each system.
 Facilities--NA
 Supply Support--spare and replacements parts are available through Base Supply System.
 Support Equipment--no special equipment required.
 Life-Cycle Inflation Cost--based on 10% increase per year 598.11 1657.92 0.0

Total Operation And Maintenance Cost for life cycle--2,256.03

Figure 8-1. Cost Analysis.